AS Unit BY2: Biodiversity and Physiology of Body Systems

Name:	Date:

Topic 2.2 Adaptations for Gas Exchange – Page 3

		Completed
1.	Read pages 2 and 3 • Label the diagram showing the cross section of a leaf. • Complete the table on page 2 and 3 that summarises the adaptations that a leaf shows to gas exchange.	
2.	Read pages 4 and 5 which detail the mechanisms that control the opening of the stomata. • Complete the questions. a. How does the structure of the guard cells around the stomatal aperture differ from that of normal epidermal cells? Include a diagram in your answer. b. Describe how guard cells open and close the stomatal apertures. Include the following in your answer: • Differential thickness of cell walls • Movement of water and ions • Water potential • Turgor pressure c. Outline the factors that influence the opening and closing of stomata.	
3.	Look at the hand out of the cactus. This is an example of plant known as a xerophyte. • How have they adapted their leaves and when they open their stomata to cope with water stress?	

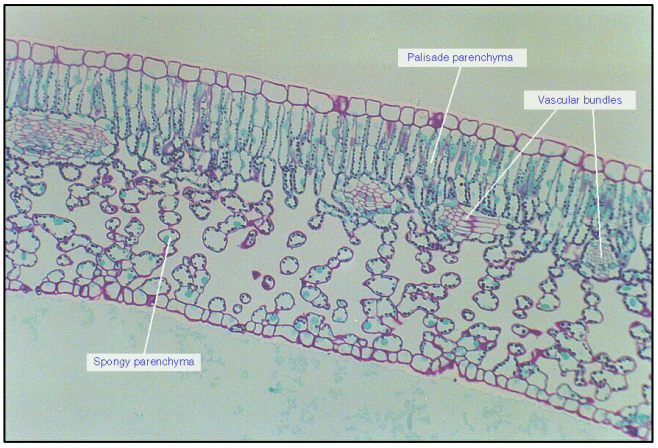
Gas Exchange in Plants

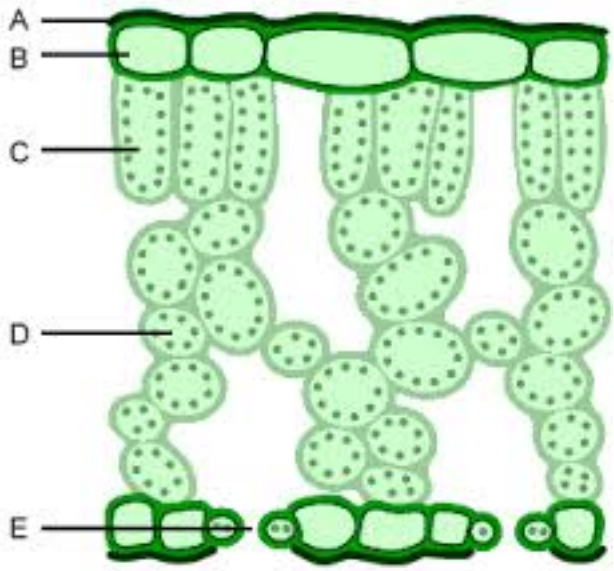
Terrestrial plants have a body, which is divided into 3 organ systems: the roots stem and leaves. The leaf is an active organ that respires at all times and photosynthesises when it receives enough light energy. Plants have to be adapted to carry out efficient gas exchange and as well as carry out their primary function, photosynthesis.

Plants rely entirely on diffusion for gas exchange. They do not possess muscular systems that bring about ventilation!

Plants will have to carry out gas exchange for photosynthesis during the day and respiration during the evening.

Why will plants not need to carry out gas exchange for the purpose of respiration during the day?





The leaves of plants are highly adapted organs.

A. Some adaptations make the leaf good at ABSORBING LIGHT

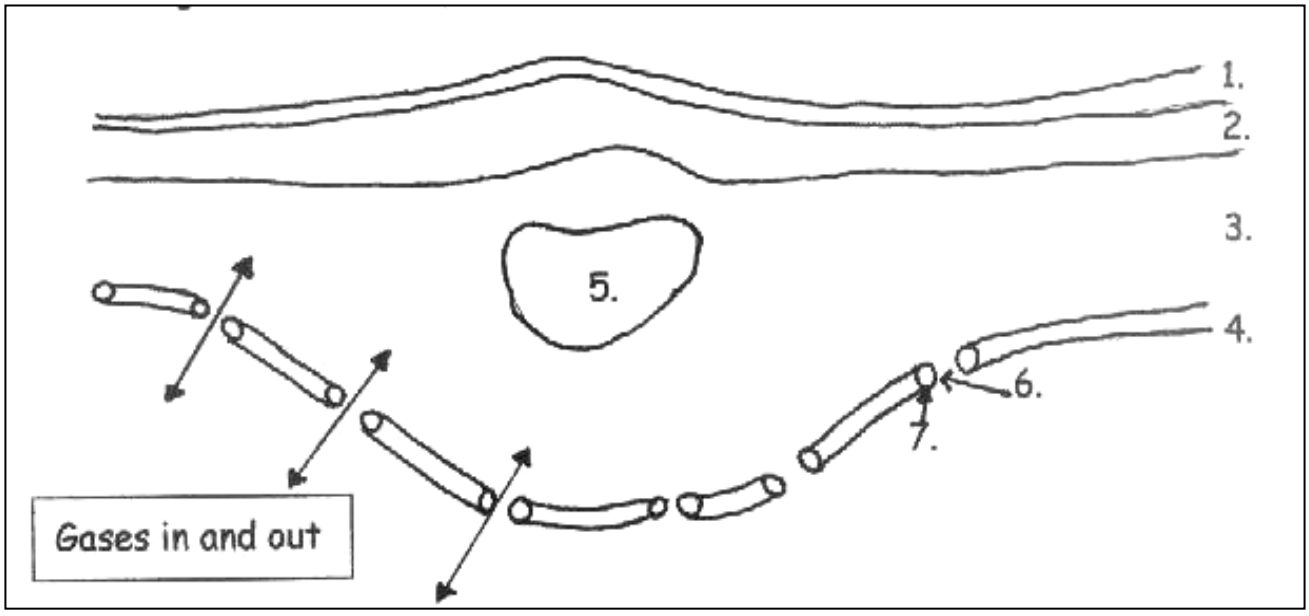
Feature	Explanation
1. The leaf stalks (petioles) bend throughout the day	
2. Leaves are arranged in a mosaic pattern (spread out evenly around the stem)	
3. Leaves are usually broad and flat	
4. The mesophyll cells contain chloroplasts	

5. The palisade mesophyll cells are tightly packed and have most chloroplasts	
6. Upper epidermis is thin and transparent	
7. The chloroplasts can rotate and move within the cells.	

B. Some adaptations make the leaf good at **GAS EXCHANGE**

Feature	Explanation
1. Leaves are thin	
2. The waxy cuticle is penetrated by many stomata (plural of stoma)	
3. There are air spaces between the spongy mesophyll cells	

The loosely packed mesophyll cells with their wet cell walls inevitably lose a lot of water to the environment. The upper epidermis of most plants secretes a waxy cuticle to try and minimise water loss.
The diagram below is a plan diagram of the tissues found in a leaf:



Identify and label the tissues.

Diffusion of Gases into the Leaf

Stomata are pores that in most plant species are more numerous on the underside of the leaf. Each pore, or stoma, is surrounded by 2 guard cells that can alter their shape to open or close the hole. This can help to control gas exchange and water loss.

Gases will diffuse through the stomata down a concentration gradient. Once inside the leaf the gases will move into the intercellular air spaces in the spongy mesophyll.

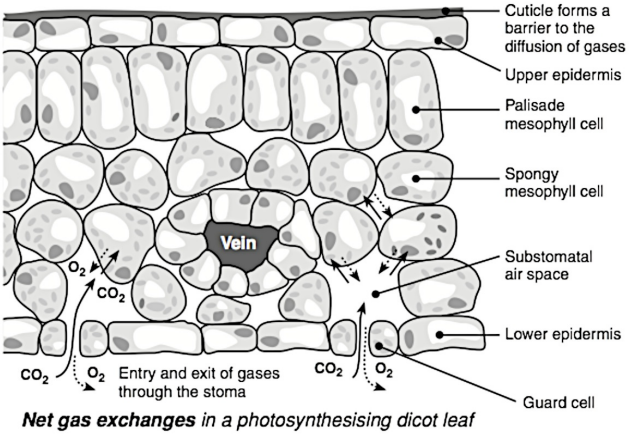
The leaf epidermis of angiosperms is covered with tiny pores, called **stomata**. Angiosperms have many air spaces between the cells of the stems, leaves, and roots. These air spaces are continuous and gases are able to move freely through them and into the plant's cells via the stomata. Each stoma is bounded by two **guard cells**, which together regulate the entry and exit of gases and water vapour. Although stomata permit gas exchange between the air and the photosynthetic cells inside the leaf, they are also the major routes for water loss through transpiration.

Gas Exchanges and the Function of Stomata

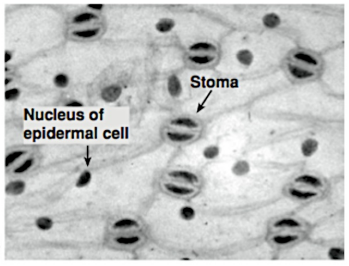
Gases enter and leave the leaf by way of stomata. Inside the leaf (as illustrated by a dicot, right), the large air spaces and loose arrangement of the spongy mesophyll facilitate the diffusion of gases and provide a large surface area for gas exchanges.

Respiring plant cells use oxygen (O_2) and produce carbon dioxide (CO_2). These gases move in and out of the plant and through the air spaces by diffusion.

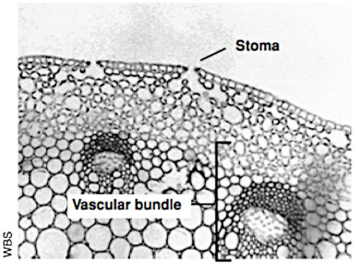
When the plant is photosynthesising, the situation is more complex. Overall there is a net consumption of CO_2 and a net production of oxygen. The fixation of CO_2 maintains a gradient in CO_2 concentration between the inside of the leaf and the atmosphere. Oxygen is produced in excess of respiratory needs and diffuses out of the leaf. These **net** exchanges are indicated by the arrows on the diagram.



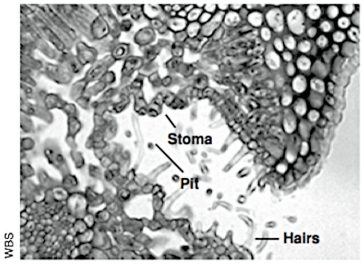
***Net gas exchanges** in a photosynthesising dicot leaf*



A surface view of the leaf epidermis of a dicot (above) illustrating the density and scattered arrangement of stomata. In dicots, stomata are usually present only on the lower leaf surface.



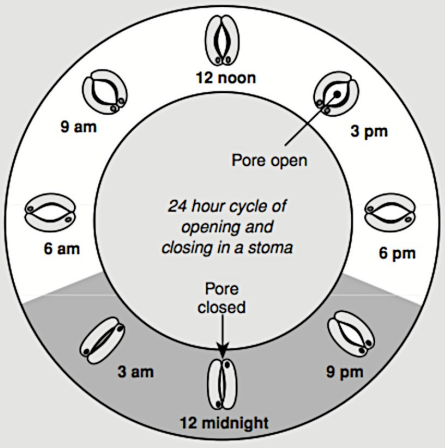
The stems of some plants (e.g. the buttercup above) are photosynthetic. Gas exchange between the stem tissues and the environment occurs through stomata in the outer epidermis.

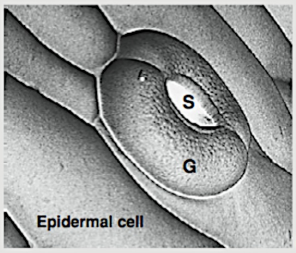


Oleander (above) is a xerophyte with many water conserving features. The stomata are in pits on the leaf underside. The pits restrict water loss to a greater extent than they reduce CO_2 uptake.

The cycle of opening and closing of stomata

The opening and closing of stomata shows a daily cycle that is largely determined by the hours of light and dark.





The image left shows a scanning electron micrograph (SEM) of a single stoma from the leaf epidermis of a dicot.

Note the guard cells (G), which are swollen tight and open the pore (S) to allow gas exchange between the leaf tissue and the environment.

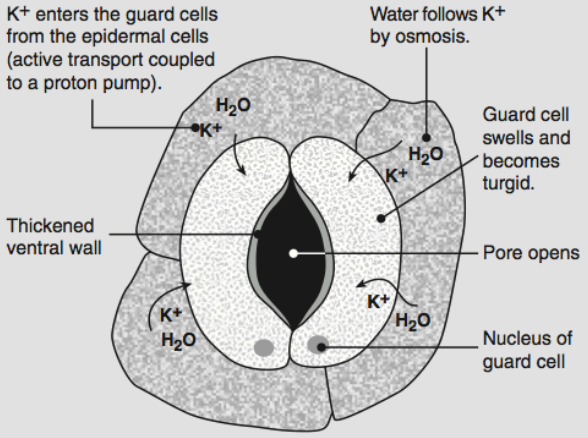
Factors influencing stomatal opening

Stomata	Guard cells	Daylight	CO_2	Soil water
Open	Turgid	Light	Low	High
Closed	Flaccid	Dark	High	Low

The opening and closing of stomata depends on environmental factors, the most important being light, carbon dioxide concentration in the leaf tissue, and water supply. Stomata tend to open during daylight in response to light, and close at night (left and above). Low CO_2 levels also promote stomatal opening. Conditions that induce water stress cause the stomata close, regardless of light or CO_2 level.

The guard cells on each side of a stoma control the diameter of the pore by changing shape. When the guard cells take up water by osmosis they swell and become turgid, making the pore wider. When the guard cells lose water, they become flaccid, and the pore closes up. By this mechanism a plant can control the amount of gas entering, or water leaving, the plant. The changes in turgor pressure that open and close the pore result mainly from the reversible uptake and loss of potassium ions (and thus water) by the guard cells.

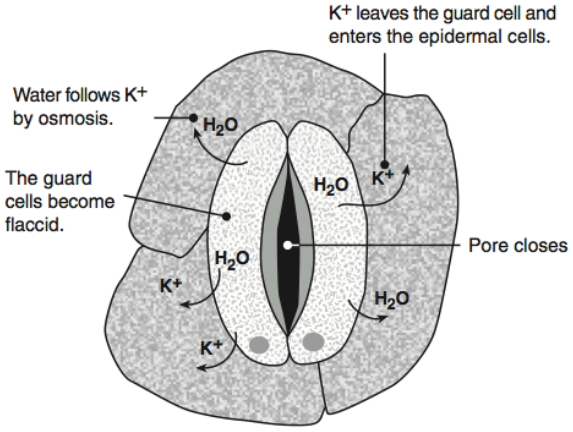
Stomatal Pore Open



ψguard cell < ψepidermal cell: water enters the guard cells

Stomata open when the guard cells actively take up K^+ from the neighbouring epidermal cells. The ion uptake causes the water potential (ψ) to become more negative in the guard cells. As a consequence, water is taken up by the cells and they swell and become turgid. The walls of the guard cells are thickened more on the inside surface (the ventral wall) than the outside wall, so that when the cells swell they buckle outward, opening the pore.

Stomatal Pore Closed



ψepidermal cell < ψguard cell: water leaves the guard cells

Stomata close when K^+ leaves the guard cells. The loss causes the water potential (ψ) to become less negative in the guard cells, and more negative in the epidermal cells. As a consequence, water is lost by osmosis and the cells sag together and close the pore. The K^+ movements in and out of the guard cells are thought to be triggered by blue-light receptors in the plasma membrane, which activate the active transport mechanisms involved.

1. With respect to a mesophytic, terrestrial flowering plant:

   (a) Describe the **net** gas exchanges between the air and the cells of the mesophyll in the dark (no photosynthesis):

   _____

   (b) Explain how this situation changes when a plant is photosynthesising: _____

   _____

   _____

2. Identify two ways in which the continuous air spaces through the plant facilitate gas exchange:

   (a) _____

   (b) _____

3. Outline the role of stomata in gas exchange in an angiosperm: _____

   _____

   _____

4. Summarise the mechanism by which the guard cells bring about:

   (a) Stomatal opening: _____

   _____

   _____

   _____

   (b) Stomatal closure: _____

   _____

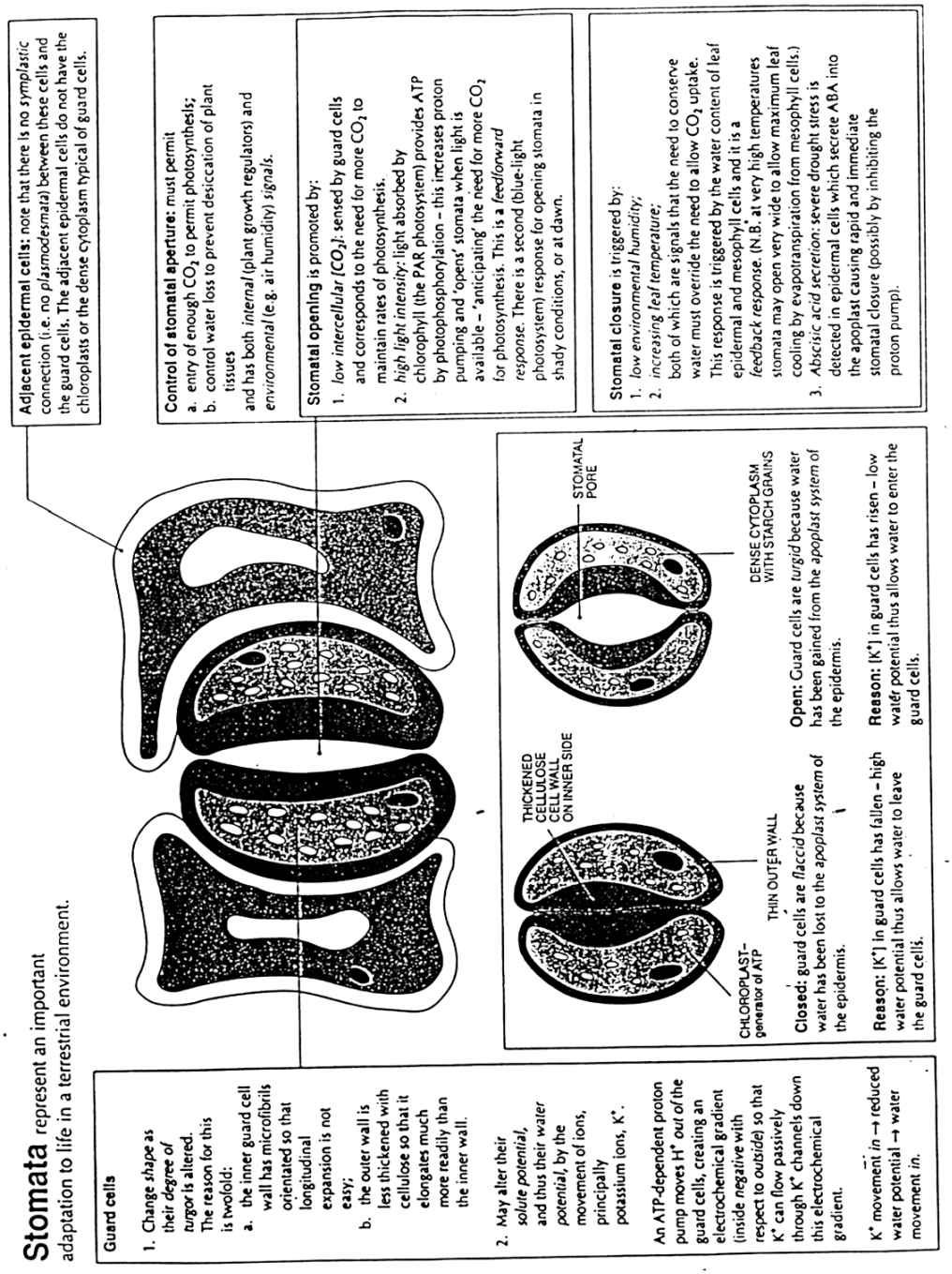
   _____

   _____

There are many theories about the mechanisms involved in the control of stomatal opening and closing. You only have to know about the **malate theory.** This theory suggests the following mechanism:

- Guard cells can carry out photosynthesis as they have chloroplasts
- During the daylight hours they carry out photosynthesis and produce ATP
- The ATP is used to actively transport K^+ into the guard cells, this triggers the breakdown of starch into malate
- The malate causing a lowering of solute potential which draws water into the guard cells
- The guard cells become turgid and open as a pore due to the uneven cell wall thickness.

Water entering the guard cells makes them turgid and water leaving the guard cells makes them flaccid.



Xerophytes are plants that show adaptations for living in areas where obtaining fresh water is a challenge. Cacti are a classic example of a xerophytic plant.